

ROADSIDE HAWK BREEDING ECOLOGY IN FOREST AND FARMING LANDSCAPES

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ABSTRACT.—We compared breeding ecology, density, and reproductive success of Roadside Hawks (*Buteo magnirostris*) in two Guatemalan study areas during 1993 and 1994. Primary forest supported 1.15 territorial pairs/km² whereas a slash-and-burn farming landscape supported 1.41 territorial pairs/km². All nests ($n = 32$) were in emergent trees. Hawks nested selectively in low canopy, seasonally inundated primary forest, and spacing of nests was related to the distribution of this forest type. Pairs did not nest selectively in a particular habitat in the farming landscape, but nested in isolated, emergent trees. Nest success (proportion of attempts that produced ≥ 1 fledgling) was 0.17 in the forested area and 0.30 in the farming landscape. Productivity (fledglings per territorial pair) was 0.08 in the forest and 0.32 in the farming landscape. Incidence of non-nesting by territorial pairs was greater in the forest (50%) than in the farming area (20%). The overall rate of nesting by territorial pairs was 65%. The most frequently identified cause of nest failure in the farming landscape was human persecution, while in the forest it was predation. Prey delivery rates did not differ significantly between habitats. Received 7 December 2000, accepted 8 April 2002.

Habitat modification by humans continues to affect a growing portion of the forested tropics. Slash-and-burn or shifting cultivation is a prevalent agent of forest alteration in many areas (Myers 1980). This type of farming involves cutting, burning, and cultivation of the forest for 1–4 years followed by leaving the area fallow for several years before it is again farmed or converted to pasture (Peters and Neuenschwander 1988). This activity produces a constantly changing mosaic of clear cuts, crop fields, woody second growth, pastures, abandoned shrublands, monocultures of cosmopolitan species such as bracken fern (*Pteridium aquilinum*), and mature forest fragments. These habitat changes may affect availability of nest sites (Newton 1992, Janes 1994), food, and important features of hunting habitat for raptors as well as their breeding density, productivity, and survivorship (Gargett 1975, Newton et al. 1986, Watson et al. 1992). Direct human persecution may be an additional important mortality source (Thiollay 1984, Alvarez-Cordero 1996).

It is unknown how the dynamic nature of slash-and-burn farming landscapes affects the

demography of raptors and which of several potential mechanisms of impact may be important for different raptor species. While some studies have described shifts in composition of tropical raptor communities in concert with different land uses (Thiollay 1993, 1996; Jullien and Thiollay 1996), no study, to our knowledge, has examined the demographic consequences of habitat alteration for any tropical forest raptor. Such knowledge might aid in management of tropical agroecosystems to sustain intact raptor communities.

We selected the abundant and conspicuous Roadside Hawk (*Buteo magnirostris*) as a subject for studying the effects of slash-and-burn farming on a tropical raptor. Wetmore (1965), Brown and Amadon (1968), and Bierregaard (1994) provided summary accounts of Roadside Hawk biology, and other authors presented brief information on diet and hunting (Haverschmidt 1962, Beltzer 1990), and on systematics and morphology (Hellmayr and Conover 1949, Friedmann 1950, Johnson and Peeters 1963, Blake 1977). These hawks often are associated with thinned forests, forest edges, and natural or anthropogenic clearings (Bierregaard 1994). Earlier work at our study site revealed Roadside Hawks nesting in primary forest (Vásquez and Reyes 1992) and found these raptors common in both primary forest and human-modified habitats (Whitacre et al. 1992a, 1992b). It was not known, however, whether habitat alteration was beneficial

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or detrimental to the species. Our objective was to document aspects of Roadside Hawk breeding ecology, with emphasis on comparing these attributes in primary forest and a slash-and-burn farming environment.

METHODS

Study area.—Our two study sites were 25 km apart in and near Tikal National Park (17° 11' N, 89° 48' W), Guatemala. Topography is relatively level with low, rolling hills 160–350 m in elevation. Mean annual rainfall is 136 cm with a pronounced dry season February to May. There are no permanent streams in the area; during the dry season, surface water is found only in a few water holes. The 576-km² Tikal National Park supports mostly unlogged, mid-height to tall semideciduous tropical forest (Pennington and Sarukhan 1968). Forest vegetation varies as a continuum along a topographic and soil type gradient from well-drained to poorly drained sites (Schulze and Whitacre 1999). We focused on the readily recognizable “bajo” and “upland” forest extremes. The bajo forest type includes Schulze and Whitacre’s (1999) hill-base, sabal, transitional, and scrub-swamp forest types, all of which grow in low-lying areas; the scrub swamp types retain standing water during the rainy season. These low-ground forest types feature low (10–17 m), relatively open canopies with a few 15–25 m emergent trees and a dense, vine rich understory. Upland forests occur on well-drained sites and are characterized by complex structure, a tall (20–30 m), closed canopy, and a thin, well-shaded understory (Schulze and Whitacre 1999).

The primary forest site, near the center of Tikal National Park, was an 8.25-km² (5 × 1.65 km) area containing transects every 100 m, and was imbedded in an immense area of mature forest (>15,000 km²). Bajo forest occurred as small patches in swales surrounded by upland forest on gentle ridges. A dirt road passed through one end of the area. The slash-and-burn study site (8 km², 4 × 2 km) was 10 km south of the Park, within an extensive area of human-modified habitat. This study area contained disturbed fragments of primary upland and bajo forest, crop fields (mostly corn), pastures, clear cuts, bracken fern monocultures, and land in successional stages from low brush to 10-m second growth. Less than 10% of the study site was covered by mature forest remnants. Several livestock watering holes dotted the landscape and an asphalt road passed through the area.

Breeding density.—We systematically searched for Roadside Hawks in each habitat from March through May. Each transect was walked twice, on different days, at different times (morning and late afternoon) and by different individuals. We stopped every 100 m for 1 min to listen and look for Roadside Hawks, noting all activity on a map. We searched a new area each day until the entire study site was completed. In addition to the systematic searches, we searched both habitats throughout the breeding season to locate all territorial pairs.

Areas of Roadside Hawk activity were revisited by 2–3 persons to find a nest or verify non-nesting. Roadside Hawks often vocalized from the nest or perch tree for a brief period after sunrise. Before dawn, one person climbed a tree using climbing equipment and waited for Roadside Hawk activity. The other individuals searched on foot and waited for hawks to call ≥ 3 times from the same tree before approaching. Nest trees were not flagged nor approached again except as noted below. Once we located all nests and pairs each year, we searched each area again and broadcast Roadside Hawk defense calls using Johnny Stewart Game and Animal Callers (Waco, Texas). Nesting and territorial pairs responded to the broadcasts throughout the breeding season by issuing defense calls, aerial displays, and/or perching in trees near the game caller; no additional pairs or nests were found through these efforts.

Although few adults were banded, we could distinguish different pairs by their reliable occurrence in small, specific portions of the study areas. Pairs were omitted from density calculations if more than half their territory was outside the study site boundary, and pairs with nests along the boundary (e.g., 10 m inside or outside) were regarded as having half their territory within the site. We also estimated density for the forest site using a plotless, polygon-based method. A convex polygon was extended to half the mean internest distance around all nest sites, and the resultant area was divided by the number of territories contained therein (Watson 1990, Berkelman 1993). We calculated mean internest distance among neighbors using the minimum spanning tree method (Selås 1997), and compared the two study sites using the Mann-Whitney *U*-test (Sokal and Rohlf 1981).

Productivity.—We checked each territorial pair every 3–6 days throughout the breeding season to record territory occupancy, nesting incidence, and nest success. Nesting pairs were those that built a nest and laid ≥ 1 egg. Non-nesting territorial pairs defended a territory but did not lay an egg (nor did they complete a nest). We climbed a nearby tree or the nest tree to record clutch size after a female began incubating. When a nest failed, we searched the area for evidence of the cause of failure. We assessed productivity by visiting nests during June and July and counting fledged young. Nest success was the proportion of nesting attempts that produced ≥ 1 fledgling. Productivity was the number of young fledged per territorial pair, including non-nesting pairs (Steenhof 1986). This measure better assesses reproduction than some alternative measures, because it includes all types of failure, including territorial pairs’ failure to nest (Newton 1979).

Prey delivery rates.—We observed four slash-and-burn nests for 229.5 h and two forest nests for 137.4 h from April to June 1994 to examine prey delivery rates. We observed from blinds on the ground and in trees ≥ 30 m from nests, using 10× binoculars and a spotting scope. We observed nests from dawn to dusk (13 h), changing observers at noon.

Nest site and habitat characteristics.—We measured several habitat variables around each nest once a nest failed or young fledged. We determined latitude and longitude at all nest trees and study site corners using a TransPak II Global Positioning System (Trimble Navigation, Sunnyvale, California), recording the mean of ≥ 20 readings. We measured macrohabitat variables at 20-m intervals along 300-m transects in the four cardinal directions from each nest tree. At each of these intervals we also noted habitat type (e.g., bajo forest, pasture, crop field) and, because of the variability in the slash-and-burn habitat, we took three canopy height measurements (Haga altimeter; Forestry Suppliers, Jackson, Mississippi) facing each cardinal direction from the same position. We used linear regression to examine whether canopy height increased with distance from nest sites. We measured the following microhabitat variables at each nest: nest tree species, height, and diameter (dbh); nest height, length, and width; and distance to the nearest tree of similar (equal or greater) height. We measured mean canopy height 5 m in each cardinal direction from the nest tree.

We measured the same variables at 40 random points to characterize potential nesting habitat in each study site; a random number generator selected UTM coordinates for sampling. Once the approximate point was located, we selected the nearest tree >10 cm in diameter and took measurements as described above. We compared habitat characteristics at nest sites and random points using Mann-Whitney *U*-tests.

We mapped forest types throughout the primary forest site to examine whether Roadside Hawks nested disproportionately often in a specific forest type. We walked 84.15 km of transects within the area (51 1.65-km transects spaced 100 m apart), and noted the forest type every 50 m. Forest at each point was designated upland, bajo, or transitional, after Schulze and Whittacre (1999). We used a *G*-test (Sokal and Rohlf 1981) to determine whether Roadside Hawks nested selectively in bajo or upland forest compared to the availability of these habitats in the forest site. We did not map cover types in the slash-and-burn site due to continued disturbance; here, selectivity with regard to nest habitat was evaluated using the 40 random points described above.

All statistical tests were performed using SAS Version 6 (SAS Institute, Inc. 1989). Significance tests were performed at $\alpha = 0.05$, with critical values adjusted where appropriate using a sequential Bonferroni procedure (Rice 1989).

RESULTS

Density.—We determined locations of 14 territories in the forest area, with ≤ 13 occupied during a given year. During 1993, five of 13 pairs (38.5%) nested, while during 1994, seven of 11 pairs (63.6%) nested. There were 10 pairs within the site's boundaries during 1993 and nine during 1994, for a mean density

of 9.5 territorial pairs/8.25 km² (1.15 territorial pairs/km²). A polygon-based method gave a density of 1.18 territorial pairs/km², very similar to the above result.

We also found 14 territories in the slash-and-burn area, of which 12 were occupied in 1993 and 13 in 1994. Unlike the forest site, percent of territorial pairs that nested differed little between years; in 1993 10 of 12 territorial pairs (83.3%) nested, while in 1994, 10 of 13 pairs (76.9%) nested. Eliminating partial territories, the mean density was 11.25 territorial pairs/8 km² (1.41 territorial pairs/km²). For nesting pairs, the 2-year mean density for the forest site was 6 nesting pairs/8.25 km² and 10 nesting pairs/8 km² in the farming landscape.

We observed 17 territorial pairs that copulated, courted, carried sticks, and defended territories, but did not finish nest building. We saw these pairs attacking conspecifics and other raptors and/or displaying in their territorial areas throughout the breeding season. All non-nesting territorial birds ($n = 34$) had adult plumage and yellow irides, an adult characteristic, hence presumably were adults and physiologically capable of breeding. The forest site had a higher incidence of non-nesting among territorial pairs (50%, 12 of 24) than did the slash-and-burn area (20%, 5 of 25; $G = 4.971$, $df = 1$, $P = 0.026$; Table 1).

Nearest-neighbor distances between occupied nest sites differed between the two study areas (Mann-Whitney *U*-test; $U = 150$, $P = 0.005$). Internest distances in the forest were extremely variable, ranging from 494–2,580 m (mean = $1,156 \text{ m} \pm 750 \text{ SD}$, $n = 10$), and reflected the distance between areas of bajo forest. Nest sites in the farming landscape were closer together (mean = $480 \text{ m} \pm 193 \text{ SD}$, $n = 11$), with distances between occupied nest sites ranging from 252–904 m.

Productivity.—We recorded 20 one-egg and 8 two-egg clutches, with a mean clutch size of $1.29 \pm 0.46 \text{ SD}$ ($n = 28$). Six of 17 nests (35%) in the slash-and-burn area had two-egg clutches, compared to two of 11 nests (18%) in the forest ($G = 0.998$, $df = 1$, $P = 0.32$).

Productivity and nest success were low. Combining all data, productivity was 0.2 fledglings per territorial pair per year, and only 25% of nesting efforts resulted in ≥ 1 fledged young (Table 1). Low productivity was due in

TABLE 1. Roadside Hawk nesting in two habitats, Petén, Guatemala.

Variable	Forest			Slash-and-burn farming		
	1993	1994	Total	1993	1994	Total
Number of non-nesting pairs	8	4	12	2	3	5
Number of nesting pairs	5	7	12	10	10	20
Number of successful nests	1	1	2	4	2	6
Number of nests with eggs that failed	3	5	8	4	4	8
Number of nests with young that failed	1	1	2	2	4	6
Number of fledglings produced	1	1	2	5	3	8

part to a high incidence (35%) of non-nesting by territorial pairs. In the forest, mean productivity was 0.08 fledglings/territorial pair, and 0.17 nests were successful per nesting attempt (Table 1). Mean productivity in the slash-and-burn area was 0.32 fledglings/territorial pair, and 0.30 nests were successful per nesting attempt.

Nest failure was common in the forest, with egg and nestling mortality occurring both years (Table 1), resulting from wind ($n = 2$) and predation ($n = 3$). Predation also was suspected at four additional nests where eggshell fragments were found or eggs disappeared. Most evidence (claw marks and fur on nest trees) implicated mammals, and a tayra (*Mustelidae: Eira barbara*) was sighted near one nest. In the slash-and-burn area, nest failure was slightly more common during the egg stage ($n = 8$) than the nestling stage ($n = 6$; Table 1), and human persecution ($n = 4$) was the most frequently identified cause of nest failure. Two nest trees were cut down, leading to premature fledging in one case and nestling death in the other. Another nestling disappeared from its nest and machete marks were found on the tree. We observed two boys playing with sling shots at another nest and by noon the nest had fallen and the egg was gone. We found no evidence of the cause at four other nests where nestlings disappeared. Study pairs in both habitats ($n = 24$) whose nests failed defended territories throughout the breeding season, but did not reneest. At nests outside the study sites, we observed two cases of apparent reneesting after initial failure, but these did not involve marked birds.

We observed one case each of cannibalism and siblicide in the forest site. In 1993 a Roadside Hawk in adult plumage but with dark irides (probably a yearling) entered a nest

and ate a 14-day old chick. In 1994, we observed siblicide in a two-chick brood where the larger nestling attacked its smaller sibling until the latter fell from the nest. We suspected siblicide at another forest nest where one nestling disappeared and the other fledged two weeks later. We saw no aggression between nestlings while monitoring five two-chick broods in the slash-and-burn area.

Prey delivery.—Reptiles (57%) and amphibians (24%) comprised most prey items at nests, with mammals representing 8%, insects 9%, and birds 2% ($n = 140$ prey items; Panasci and Whitacre 2000). Per-chick prey delivery rates did not differ significantly between nests in the forest and farming habitats (Mann-Whitney U -test; $U = 9$, $P = 0.49$), nor between one- and two-chick broods ($U = 10$, $P = 1.00$). The mean prey delivery rate at forest nests was 0.311 prey/h/chick ± 0.068 SD ($n = 2$ nests), and at slash-and-burn nests was 0.275 ± 0.134 ($n = 4$ nests). The mean delivery rate at one-chick nests was 0.264 prey/h/chick ± 0.095 SD ($n = 3$ nests), and at two-chick nests was 0.311 ± 0.140 ($n = 3$ nests). We detected no significant difference in the per-nest total prey delivery rates between nests in the two habitats (Mann-Whitney U -test; $U = 5$, $P = 0.49$). The mean rate at forest nests was 0.366 prey/h/nest ± 0.010 SD ($n = 2$ nests), and at slash-and-burn nests was 0.439 ± 0.080 ($n = 4$ nests).

Nest sites and habitat.—We found 32 Roadside Hawk nests during 1993 and 1994. All were flat, platform nests loosely built of sticks. All 12 forest nests and 12 of 20 slash-and-burn nests were concealed from above and/or below by vine tangles. Mean nest dimensions were 34.7 cm in length and 26.3 cm in width ($n = 16$), and all contained some green leaves in a slight depression in the cen-

ter. Roadside Hawks nested in emergent trees in both habitats (Table 2). The mean height of nest trees in the forest site was nearly twice the height of the surrounding canopy. Roadside Hawks nested at significantly lower heights in the slash-and-burn habitat, and in shorter, smaller diameter trees, surrounded by shorter vegetation (Table 2). However, all 20 slash-and-burn nests were in emergent trees as well, and nests in both habitats had a mean height of 7 m above the surrounding canopy.

Roadside Hawks in the primary forest site nested selectively in low-stature bajo forest, avoiding tall, upland forest. All nests ($n = 12$) were in bajo or transitional forest, even though these forest types comprised only 10.3 and 5.4% of the forest study site, respectively (the remaining 84.3% of the site supporting upland forest). Nests were in bajo forest more often than expected; of 40 random points, seven were in bajo forest and 33 in upland forest ($G = 51.56$, $df = 1$, $P = 0.0001$). In addition, forest nest sites differed in habitat from random points. Roadside Hawk nests were in taller, larger diameter trees, in forest with lower canopy height, and in trees with a greater distance to a tree of similar height, relative to the random sample (Table 2). Canopy height for the forest site increased with distance from the nest (over a 300-m distance at 20-m intervals; linear regression: $r^2 = 0.916$, $F = 141$, $P = 0.0001$), reflecting that forest nests were in areas of low canopy bajo forest surrounded by a matrix of taller, upland forest.

Values of microhabitat variables near slash-and-burn nests did not differ significantly from those at random points except that hawks nested in larger trees (Table 2). Nests in the slash-and-burn site were not detectably associated with a certain forest type, and occurred in isolated groves amidst cattle pastures, crop fields ($n = 12$), or woody successional vegetation ($n = 8$).

Reuse of nest sites between years was rare in the forest and not observed at all in the slash-and-burn area. In the forest, two 1994 nests were built in trees where nests had failed during 1993; in one case the pair reused the previous year's nest; all other 1994 nests were in trees different than those used the previous year. In addition, one 1994 forest nest tree had been used by nesting Gray-headed Kites (*Lepidodon caymanensis*) the previous year. Of the

TABLE 2. Roadside Hawk nest site characteristics in two habitats, Petén, Guatemala, 1993 and 1994. Values are mean \pm SD.

Variable	Slash-and-burn farming			Forest		
	Nests ($n = 20$)	Random ($n = 40$)	p^a nests versus random	Nests ($n = 12$)	Random ($n = 40$)	p^a nests versus random
Nest height (m)	10.63 \pm 3.30			20.26 \pm 3.01		0.0001
Tree height (m)	12.96 \pm 4.22	11.24 \pm 7.19	0.1468	23.42 \pm 3.01	17.07 \pm 2.41	0.0001
Mean canopy height (m)	3.77 \pm 3.16	5.45 \pm 6.17	0.6675	12.58 \pm 3.45	17.31 \pm 2.31	0.0001
Nest tree DBH (cm)	25.28 \pm 13.15	17.37 \pm 15.23	0.0026	53.66 \pm 23.93	34.44 \pm 15.16	0.0005
Distance to a tree of similar height (m)	7.29 \pm 7.64	5.78 \pm 4.48	0.6436	9.56 \pm 6.59	5.20 \pm 3.35	0.1240

^a Mann-Whitney U -tests. Probabilities Bonferroni adjusted.

eight territories where pairs nested during 1993 in the slash-and-burn site, each was occupied during 1994 but nests were located in different trees; the mean distance between 1993 and 1994 nest sites within a given territory was $231 \text{ m} \pm 120 \text{ SD}$ (range = 55–443 m, $n = 8$).

DISCUSSION

The low productivity we observed resulted from small clutch size, high rates of nest failure, and relatively high rates of non-nesting. The annual productivity values we found were very low for a raptor population not adversely affected by environmental contaminants (Newton 1979). Our productivity value is low even by tropical standards. In temperate zone accipitrids ($n = 15$ species), mean productivity was 1.23 fledglings/territorial pair, whereas tropical accipitrids ($n = 11$ species) had a mean productivity of 0.51 fledglings/territorial pair (as calculated from Newton 1979: Table 23).

The difference in productivity between temperate and tropical raptors (Newton 1979) was due largely to the larger mean clutch size of temperate raptors (2.8, $n = 14$ species) compared to tropical raptors (1.5, $n = 12$ species). A two-egg clutch size is reported for Roadside Hawks from Costa Rica northward (Howell and Webb 1995, Smithe 1966, Stiles and Janzen 1983). Based on 127 museum egg sets from Mexico, Central, and South America, mean clutch size for Roadside Hawks is $1.92 \text{ eggs} \pm 0.41 \text{ SDs}$ (16 one-egg, 105 two-egg, and six three-egg sets; T. A. Panasci unpubl. data), compared to the mean clutch size of 1.29 eggs that we found at Tikal. We can offer no explanation for the smaller clutch size we found; more data are needed to evaluate whether this finding is typical for this region.

Again using Newton's (1979) data, among temperate zone accipitrids ($n = 15$ species), 84% of territorial pairs nested (laid eggs), while in tropical accipitrids ($n = 12$ species, all African), 70% of territorial pairs nested ($U = 144.5$, $P = 0.008$). With 65% of territorial pairs nesting, Roadside Hawks resemble the tropical raptors cited above. However, the 25% nest success we documented was very low compared to both temperate zone ($68.3\% \pm 1.75 \text{ SE}$, $n = 17$) and tropical accipitrids ($65.9\% \pm 3.68 \text{ SE}$, $n = 12$; Newton 1979:

Table 23). Vásquez and Reyes (1992) reported two fledglings from six nests at Tikal, for a nest success of 33% and a productivity of 0.30 fledglings per nesting attempt. It is possible that our climbing to some nests to verify clutch size may have contributed to nest failure; 5 of 13 nests to which we climbed failed while only 3 of 19 nests to which we did not climb failed.

Limited nest sites and a more diverse raptor assemblage offer one potential explanation why the incidence of non-nesting by territorial pairs of Roadside Hawks was greater in the mature forest than in the farming landscape. While a few raptor species at Tikal were more abundant in the farming landscape than in the primary forest, many species were more abundant in the forest than in the farming landscape (Whitacre et al. 1992a, 1992b). The net result is that raptor species richness was much greater in the primary forest than in the farming landscape, possibly leading to greater interspecific competition. Nest sites did not appear to be a limiting resource for Roadside Hawks in the slash-and-burn site; the hawks changed nest sites each year and used trees fairly typical of those available. That two 1993 nest trees in the forest were used again during 1994, whereas no nest sites were reused in the slash-and-burn area, supports the hypothesis that nest sites were more limiting in the forest than in the farming landscape. Moreover, the change in possession of a nest tree that we noted between Gray-headed Kites and Roadside Hawks, and our finding that many raptor species at Tikal used emergent trees similar to those used by Roadside Hawks (Whitacre et al. 1992a, 1992b) point to the possibility that nest site competition may occur in the primary forest.

Primary forest and human-modified habitats in our study differed markedly in vegetation structure, and likely also differed in prey resources. However, prey delivery rates to nests in the two habitats were similar. Prey delivery rates may in some cases be a good index of habitat quality and food resources (Bennetts et al. 1994). However, a difference in prey availability between habitats might result in different proportions of territorial pairs nesting. Consequently, the lack of difference in prey delivery rates at nests in the two hab-

itats is not convincing evidence of similar foraging conditions.

Roadside Hawks consistently selected emergent nest trees from those available. In the farming landscape this was not associated with any discernible selection of a particular vegetation type. However, in the mature forest Roadside Hawks showed strong selectivity of low canopy bajo forest as nest habitat, and avoided nesting in the tall, closed canopy forest that covered 80% of the forest site. Robinson (1994) also reported that Roadside Hawks nested in isolated trees in Peru. Isolated and emergent trees, having minimal connection to adjacent canopy, may provide some safety from climbing predators.

Conservation implications.—Thiollay (1984) and Alvarez-Cordero (1996) reported that tropical forest raptors in some cases experienced high mortality due to direct persecution by humans. Even though Roadside Hawks in our study successfully nested in a slash-and-burn farming landscape, human persecution was the most frequently identified cause of nest failure there. This suggests that for other, more sensitive raptor species, persecution may be a determinant of their success in human-modified environments.

Roadside Hawks did not seem negatively affected by habitat alteration in the farming landscape. Although dramatic changes in vegetative cover occurred each breeding season in the slash-and-burn site, locations and occupancy of Roadside Hawk territories remained stable. In addition, incidence of nesting by territorial pairs, nest success, and productivity all were greater in the farming landscape than in primary forest. These results suggest that land use practices typical of slash-and-burn farming did not negatively affect our Roadside Hawk study population. Our results suggest the farming landscape at Tikal may have been a more hospitable environment for Roadside Hawks than the mature forest. This is not surprising, given that these raptors are widely known as habitat generalists (Bierregaard 1994, Panasci and Whitacre 2000). Of greater conservation importance was the noticeable amount of nest failure resulting from direct human persecution. Reducing persecution through education may increase the potential of tropical agroecosystems to retain a

maximal portion of their indigenous raptor faunas.

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